

Schizoneura manchuriensis Kon'no and its
Fructification (*Manchurostachys* n. gen.)
from the *Gigantopteris-nicotianaefolia*-
bearing Formation in Penchihiu
Coal-field, Northeastern China

Enzo Kon'no

Institute of Geology and Paleontology, Tohoku University, Sendai, Japan

INTRODUCTION AND ACKNOWLEDGEMENTS

This paper contains the description of *Schizoneura manchuriensis* Kon'no and its fructification (*Manchurostachys* n. gen.) from the Tsaichia (*Gigantopteris-nicotianaefolia*-bearing) formation, collected at about lat. 41°19'7" N. and long. 123°43' E., in the Penchihiu coal-field in Manchuria.

The present writer (1942, pp. 238-239, figs. 1, 2) reported on the occurrence of *Schizoneura manchuriensis* n. sp. from the Penchihiu coal-field and its geological significance in 1942. In the summers of 1943 and 1944, the writer visited the same coal-field and succeeded in collecting more than 100 specimens of *Schizoneura*, containing seven specimens of its fructification. All of these specimens are deposited in the Institute of Geology and Paleontology, Tohoku University, Sendai (IGPS).

Schizoneura manchuriensis resembles very closely *Sch. gondwanensis* and evidently belong to the typical *Schizoneura* which is evidence to prove that *Schizoneura*, one of the most important members of the *Glossopteris*-flora, was mingled in the typical Cathaysian flora in the older upper Permian age, when the *Gigantopteris-nicotianaefolia*-flora was most typically developed and extensively distributed in Eastern Asia.

The fructification of *Sch. manchuriensis* is composed of a regular alternation of clusters of hexasporangiferous sporangiophores and a magnificent coherent sterile leaf-sheath. By the features of both vegetative and the fertile shoots, detailed comparisons with other related plants have been carried out to find the most reasonable position of *Schizoneura* in the Equisetales. Finally the geological and the geographical distribution of *Schizoneura* and other important elements of the *Glossopteris*-flora, occurring in the Cathaysian flora, are examined in detail.

I am deeply indebted to Professor Shoshiro Hanzawa, Institute of Geology and Paleontology, Tohoku University, who kindly helped me in various ways to complete this study, especially in giving me encouragement to recover from my long illness. Thanks are also due to Dr. Hisakatsu Yabe, Professor Emeritus of the Tohoku University, who has given every available facility to use his extensive library. Finally my thanks are extended

to Professor Kiyoshi Asano and Professor Katora Hatai of the Tohoku University for their help in preparation and arrangement of publishing this paper.

I SYSTEMATIC DESCRIPTIONS

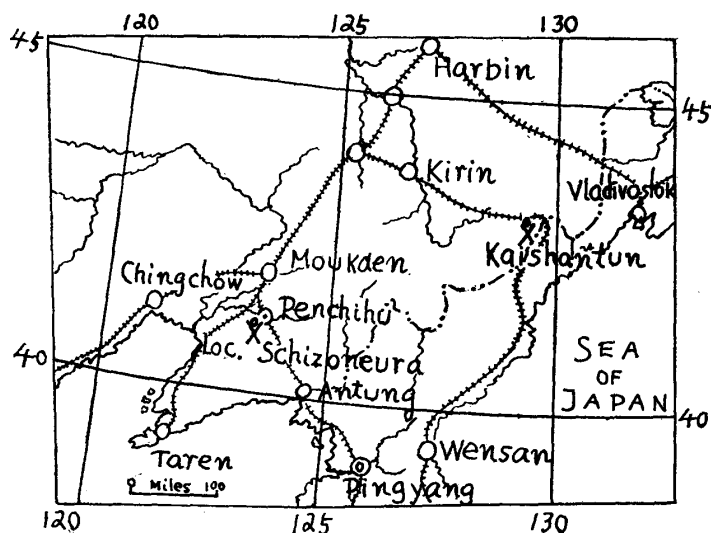
Genus *Schizoneura* Schimper et Mougeot, 1844

Schizoneura (*Manchurostachys* n. gen.) *manchuriensis* Kon'no

Type-specimens: Vegetative foliage shoots (IGPS coll. cat. nos. 78076, 78066)

Fertile shoots (IGPS coll. cat. nos. 78083, 78084)

Geological horizon and locality: Middle part of the Tsaichia formation (lower upper Permian), collected at a hillside at about lat. $41^{\circ}19'7''$ N. and long. $123^{\circ}43'$ E., about 600 m. southwest of the village of Paochiaoutze in the Penchiu coal-field, Northeastern China.



Text-fig. 1. Index map showing localities of collections of *Schizoneura manchuriensis* and Kaishantun flora.

Diagnosis:

(1) Vegetative shoot. (*Sch. manchuriensis* Kon'no). — Aerial main stem hollow, cylindrical, with internodes about 70–80 mm. long by 8–10 mm. across in its lower part and 20–30 mm. long by 5–6 mm. wide in main part, traversed by ridges and furrows which are not alternate but continuous through node from one internode to next; leaf-sheath consists of 10–16 leaves, maximum number of which being constantly 16. Lateral branches a little more than 10 in number at node of main stem, divided into more than 7 internodes, lowermost of which is far longer than the next upper, e.g. the former measures 50 mm. in length while the latter only 30 mm. (see Text-fig. 2); leaf-sheath composed of 8–14 leaves, maximum number generally 14, but rarely 16. Leaf-sheath of both main and lateral stems generally split into two equal coherent lobes, each of which spreads out amplexicauly one on each side of axis; on lower region of main stem leaf-sheath often

split completely into separate leaves free down to their bases; in immature uppermost sheath all leaves united completely and tightly together into a single coherent sheath of upturned bottle-shape, provided with a small circular opening of about 1 mm. diameter in center of its apex. Lobe of sheath is generally composed by complete fusion of leaves for their whole length, elongated oblong or often lanceolate in form, apical margin of which is truncated with short dents; each leaf linear or linear-lanceolate, measures generally 60–62 mm. in length by 1.7–2.7 mm. in width, length of which is about twice as long as adjacent internode; midrib thick, 0.6–0.8 mm. across not single but multiple being composed of 7–8 fine parallel longitudinal striations.

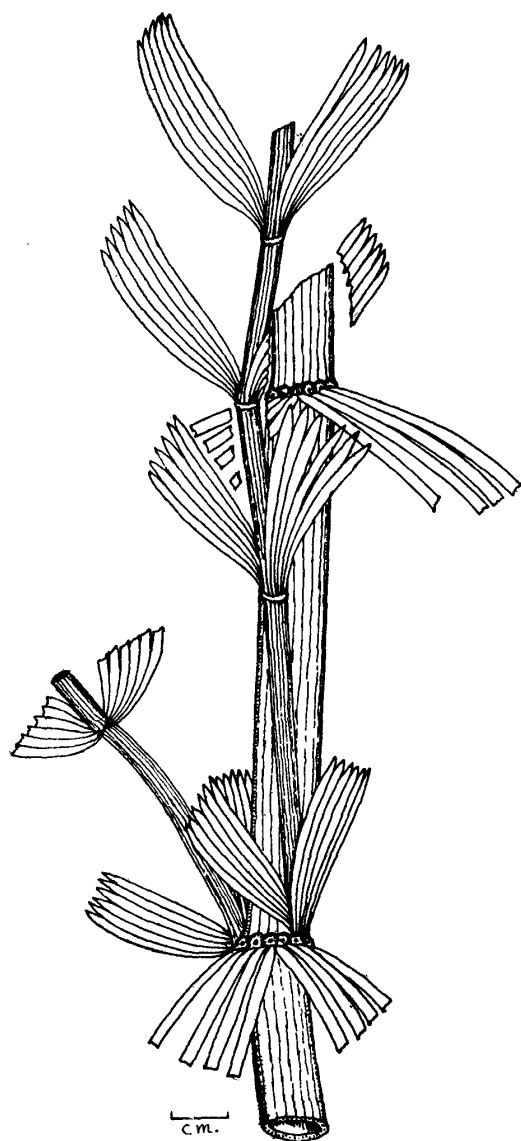
2) Fertile shoot (*Manchurostachys manchuriensis* Kon'no). — Fertile shoot long cylindrical, consisting of regular alternation of numerous whorls of simple peltate sporangiophores and a magnificent coherent sterile leaf-sheath. Sterile leaf-sheath large, of upturned cone-shape, slightly undulated at upper margin, built by intimate cohesion of all leaves in a whorl, each leaf of sheath measures 65 mm. in length by 5 mm. in maximum width and traversed uniformly by many longitudinal striations. Interval between every two successive sterile leaf-sheaths measures 5–7–10 mm. in length, covered by 6–7 whorls of sporangiophores; sporangiophores in each whorl crowded, 20–23 in number, arranged in superposition in longitudinal rows. Each sporangiophore solitary, simple in structure, composed of simple axis and hexasporangiferous polygonal peltate lamina of 1.0–1.7 mm. diameter. Sporangium ovoid, about 0.6–0.8 mm. in shorter diameter and 1 mm. in longer one, containing numerous spores of circular shape measuring 10–14 μ in diameter.

Measurements and Remarks

1) Vegetative aerial shoot. — a) Aerial foliage shoot with branches in organic connection to stem:

Specimens shown in Pl. 18, fig. 5 and Pl. 19, figs. 4a, 4b (see Text-fig. 2) (IGPS coll. cat. no. 78066).—It shows a main stem bearing two branches preserved in continuity with the node. This main stem is hollow, cylindrical, with an internode 85 mm. long by 10 mm. wide; ribs on the surface of the internode are 1.0–1.05 mm. apart, about eight to nine on the crushed fossil surface; on the decorticated specimen are seen several much finer longitudinal striations in each rib, about 0.25 mm. distant from one another, which evidently suggest the inner tissues under superficial layers. The nodes are fairly swollen with about ten scars of branch-bases, and on the lower node two branches are attached in organic connection to the stem. The one branch of them bears three internodes, the lowermost of which measures about 50 mm. long and is much longer than the next upper one of 30 mm. length as well as the third upper only 25 mm. long. This feature of this lowermost internode of the branch being extraordinarily longer than the next upper is one of the most important characteristics of the typical *Schizoneura*. The internode of the branch is generally 3.0–3.5 mm. wide, traversed by six to seven longitudinal ribs, which are approximately equal in number to a half of the leaves in a sheath on the adjacent node. The main stem of this specimen lacks entirely the leaf-segment on the node, which might have fallen away possibly during fossilization. In addition to these characters this

specimen has the longest internode among all the specimens now at disposal. Thus this specimen seems to represent the lower part of rather a large shoot.



Text-fig. 2. *Schizoneura manchuriensis*. Specimen no. 78066. Lower part of the main stem with two branches preserved in continuity with the node. It is a drawing of the specimen shown in Pl. 18, fig. 5, and Pl. 19, figs. 4a, 4b, also with additional data of the specimen shown in Pl. 19, fig. 7.

two well-defined coherent lobes, spreading outwards with nearly a right angle to the stem. The immature branch measures 37 mm. in length, terminated in a completely united leaf-sheath of 23 mm. in length and 6.5 mm. in width, composed of 14 leaves (7 leaves seen on the fossil surface); below this apical coherent sheath are several shortened internodes and leaf-sheaths, the latter of which are divided into two lobes pointing forwards and then nearly parallel to the axis. Another isolated specimen of the similar immature branch is

Specimen shown in Pl. 19, fig. 7 (IGPS coll. cat. no. 78064). — Two internodes are shown, the lower of which is about 70 mm. long by 9 mm. across, the upper one 65 mm. long by 8 mm. wide. On the surface are seen numerous fine longitudinal striations, 0.36–0.4 mm. apart, suggesting the inner tissues under the cortical layers. Three branches are preserved in continuity with the uppermost node, where about ten scars of the complicated branch-base are seen; lateral branches are about 4.5 mm. across at its lowermost internode. The leaf-sheath at the lower node are split into individual leaves free down to their bases, pointing outwards and then reflecting backwards. The branch-scar on the node is circular, about 4 mm. in diameter, composed of a central flat circular area of about 2 mm. in diameter with numerous radiating spokes and its surrounding elevated fringe, the latter of which evidently consisted of numerous scars of leaves of the branch. This specimen also represents the lower part of the main stem of the large shoot like that described just above.

Specimen shown in Pl. 19, fig. 1; Text-fig. 3 (IGPS coll. cat. no. 78065). — It contains eight internodes, eight leaf-sheaths and one lateral immature branch in continuity with the stem. The internodes of the stem are short, ranging from 15 mm. to 9 mm. in length, but numerous scars of the branches are seen on every node; the leaf-sheath is divided into

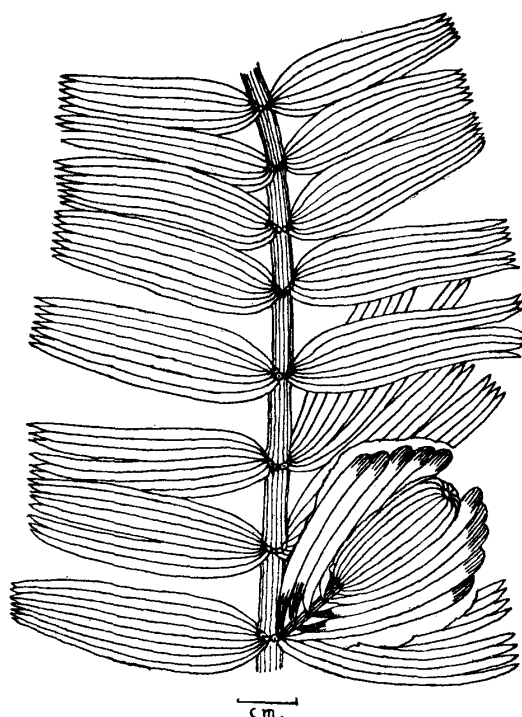
shown in Pl. 19, fig. 3b and its twice enlarged figure is given in Pl. 16, fig. 5, in which the apical coherent leaf-sheath is 19 mm. long by 7 mm. wide, composed also of 14 leaves and provided with a small circular opening on its apex.

b) Aerial foliage shoot without any preserved branch in continuity with stem, but with numerous scars of branches on nodes of stem :

Specimen shown in Pl. 19, fig. 6 (IGPS coll. cat. no. 78072). —This specimen deserves special attention, because its internodes are very thick and covered by peculiar fine appendages suggesting some rootlets. The internode is 17 mm. across and thickest of all the specimens now at hand, but is relatively short, measuring only 52–55 mm. The nodal diaphragm is somewhat clearly shown in the lower extremity of the specimen, which consists of a flat depressed circular area of 10 mm. in diameter with numerous spokes radiating from a small circular center; around this diaphragm, more than ten elevated round scars of the branches are arranged in intimate contact with one another ; on the further outside, numerous finer scars of leaf-bases of 1.3 mm. in diameter are seen being attached by about 50 mm. long leaves in continuity with them. The surface of the internode is devoid of longitudinal ribs, but characterized by numerous irregular horizontal ridges and depressions, which evidently represent the character of the outer surface of the cortex. The fine rootlet-like appendages cover densely the whole surface of the internode, each of which consists of a papilla-formed base and its long narrow prolongation of about 4 mm. in length by 0.1–0.2 mm. in width. Thus this thick specimen seems to represent the lowermost portion of the large erect foliage stem, perhaps grown near or immediately below the surface of the ground.

Specimen shown in Pl. 18, fig. 1 (IGPS coll. cat. no. 78070). — This specimen also represents a relatively thick main stem ; the internode is 60 mm. long by 9.5 mm. wide, traversed by 1.25 mm. distant longitudinal furrows, and further by several fine interstitial striations between every two successive furrows. On the nodal area are many scars of the branch-base of 1.9 mm. \times 2.1 mm. in diameters.

Specimen shown in Pl. 16, fig. 1 (IGPS coll. cat. no. 78075).— It represents the middle part of the main stem ; the internode is 26 mm. long by 5.5 mm. wide ; the leaf-sheath is



Text-fig. 3. *Schizoneura manchuriensis*. Specimen no. 78065. Upper part of the main stem, with a short immature branch preserved in organic connection with the main stem ; the terminal leaf-sheath of the branch is composed by thorough fusion of all the leaves in a whorl into a coherent sheath of upturned bottle-shape. It is a drawing of the specimen shown in Pl. 19, fig. 1, slightly restored.

divided into two distinct lobes, each of which is apt to split into separate sheath-segments or individual leaves. The leaf is longer than the normal examples, measuring 62 mm. in length, which is about 2.4 times as long as the adjacent node.

Specimen shown in Pl. 17, fig. 4 (IGPS coll. cat. no. 78074). — It represents also the middle part of the main stem; leaf-sheath is divided into two distinct coherent lobes, each of which consists of eight leaves. The characteristic feature of the midrib of the leaf is clearly shown in this specimen: the leaf is 1.7–2.5 mm. wide, traversed by 0.9 mm. thick midrib, which is composed of about 7 longitudinal striations.

Specimen shown in Pl. 17, fig. 3 (IGPS coll. cat. no. 78077). — The thickness of the stem is nearly equal to those of the two specimens described above, but five internodes of this specimen reduce their length rapidly upwards from 30 mm. to 9 mm. The leaf-sheath is divided into tightly coherent lobes, composed of eight leaves in general. Thus this specimen appears to represent the upper part of a large well-developed main stem.

Specimen shown in Pl. 16, fig. 2 (IGPS coll. cat. no. 78075). — Though the internode is narrow and only 12 leaves in a whorl, this specimen appears to represent the lower portion of rather a small main stem, because distinct scars of branch-base are seen on a majority of the nodes and leaves on its lower nodes are free down to their bases and often reflected downwards.

Specimen shown in Pl. 16, fig. 3 (IGPS coll. cat. no. 78076). — In this well-preserved specimen, ten internodes are seen to be shortened rapidly from the 25 mm. long basal internode to the 6.5 mm. long apical one, the basal sheath-lobe is 45 mm. long by 18 mm. wide and composed of seven leaves, whereas the apical one is only 15 mm. long with four leaves. Thus it is evident that this specimen represents the middle and the apical parts of a fully developed foliage shoot. The apical end of this specimen is not terminated in the large fan-shaped terminal whorl, by which *Schizoneura* can safely be discriminated from *Lobatannularia* and its allied forms.

c) Aerial foliage shoot without either preserved branch or scar of branch-base:

Specimen shown in Pl. 18, fig. 3 (IGPS coll. cat. no. 78067). — Stem is narrow 2.5–3 mm. across, sheath-lobes on each side are inserted asymmetrically upon the stem, no branch-scar is found on the node, etc., all of which seem to suggest strongly that this specimen belongs to a lateral branch of possibly a once-branched main stem.

Specimen shown in Pl. 17, fig. 5 (IGPS coll. cat. no. 78078). — This specimen appears to represent the typical lateral branch, because the stem is thin and slightly flexuous, sheath-lobes are composed of tightly fused leaves, no trace of the branch-base can be seen on the node.

Specimen shown in Pl. 17, fig. 2 (IGPS coll. cat. no. 78082). — This small specimen resembles closely the apical part of the specimen shown in Pl. 16, fig. 3, and though no branch-scar is seen on the nodes, it may represent also the apical end of some main stem. The internodes and sheath-lobes reduce rapidly their size towards the apex, where a small undeveloped leaf-sheath is seen.

d) Conclusion on the aerial foliage shoot. — (1) The vegetative aerial shoot is generally once-branched, with about ten branches of equal size being given off in radial

Table Showing numerical measurements of specimens
(all in mm.)

a) Aerial foliage-stem with branches preserved in continuity on stem.

IGPS cat. no.	Pl. & fig. no.	Main stem						Branch	
		internode			leaf-sheath			internode	leaf-sh.
		A	B	C	D	E	F	B	E
78066	Pl. 19 f.4a, 4b	3	II=85×10	?	?	?	?	I=50×3.5 II=30×3.0 III=25×?	
78064	Pl. 19 f.7	2	I=+70×9 II=65×8				45(+) ×2	I=?×4.5	
78065	Pl. 19 f.1	8	I=15×5.2 IV=13×3.3 VII=9×2.5	I-VII= 15-9	38/14= 2.7	14	38×1.8		14

b) Aerial foliage-stem with scars of branches on node, but without preserved branch.

IGPS cat. no.	Pl. & fig. no.	Main stem						Branch
		internode			leaf-sheath			
		A	B	C	D	E	F	G
78072	Pl. 19 f.6	2	I=52×17 II=55×17	?	?	16	+50×?	3.5×4.0
78070	Pl. 18 f.1	3	II=60×9.5	?	?	?	?	2.1×1.9
78075	Pl. 16 f.1	5	I=26×5.5 II=25×5.0 IV=22×4.5	I-IV= 26-22	62/?	?	62×2.5	2.2-2.4
78074	Pl. 17 f.4	5	II=30×5.5 V=20×5.0	II-V= 30-20	55/12= 4.5	16	52×2.2	+
78077	Pl. 17 f.3	6	II=30×5.6 IV=14×4.9 VI=9×4.8	II-VI= 30-9	50/20= 2.5	16	50×2.4	+
78076	Pl. 16 f.3	10	II=25×3, IV= 19×2.5, VII= 14×2.1, X=6.5 ×?	II-X= 25-6.5	45/18= 2.5	14	45×2.3	+
78068	Pl. 18 f.6	7	I=26×4.6, III=25×3.4, VI=23×2.5	I-VI= 26-23	47/16= 3.0	16	47×2.1	?

symmetry from the node. (2) The internodes of the main stem measure 60-85 mm. long by 10 mm. wide in the lower part, 20-30 mm. long by 5-6 mm. across in the middle part, and in the upper part both of the internodes and the sheath-lobes reduce rapidly their length and size towards the apex, where no terminal fan-shaped whorl of leaves is developed. (3) The internodes of both main stem and the lateral branch are traversed by ridges and grooves, which pass through the nodal line in continuity from one internode to the next; when decorticated, several fine longitudinal striations are seen between every

c) Aerial foliage-stem without scar of branch on node

IGPS cat. no.	Pl. & fig. no.	internode			leaf-sheath		
		A	B	C	D	E	F
78067	Pl. 18 f.3	8	I=20×3, III=17×2.8, VI=17×2.5	I-VI= 20-17	34/11.5= 3.0	14	34×2.2
78078	Pl. 17 f.5	6	I=16×2.4, III=15×2.2, VI=12.5×1.0	I-VI= 16-12.5	28/13= 2.2	14	30×2.2
78063	Pl. 18 f.2	7	II=15×2.2, III=12×1.7, VI=10×1.0	II-VI= 15-10	?	12	?
78080	Pl. 18 f.4	6	I=12×2.5, III=10×2.1, V=9.5×1.9	I-V= 12-9.5	19/8.5= 2.2	10	19×1.7
78082	Pl. 17 f.2	6	I=15×2.3, III=11.5×?, V=4.5×?	I-V= 15-4.5	29/8.5= 3.4	12	29×1.7
78069	Pl. 19 f.2	4	I=10.5×2.5 III=9.5×?	I-III= 10.5-9.5	23/8.5= 2.7	14	23×2

A : Number of preserved internodes, B : Length × Width of internode, C : Range of variation in length of internode, D : Length/Width of sheath-lobe, E : Maximum number of leaves in a sheath, F : Length × Width of leaf-segment, G : Diameters of scar of branch-base on the node. I, II, etc. mean the first internode, the second, and so on, counting from the lowermost internode of the specimen successively upwards.

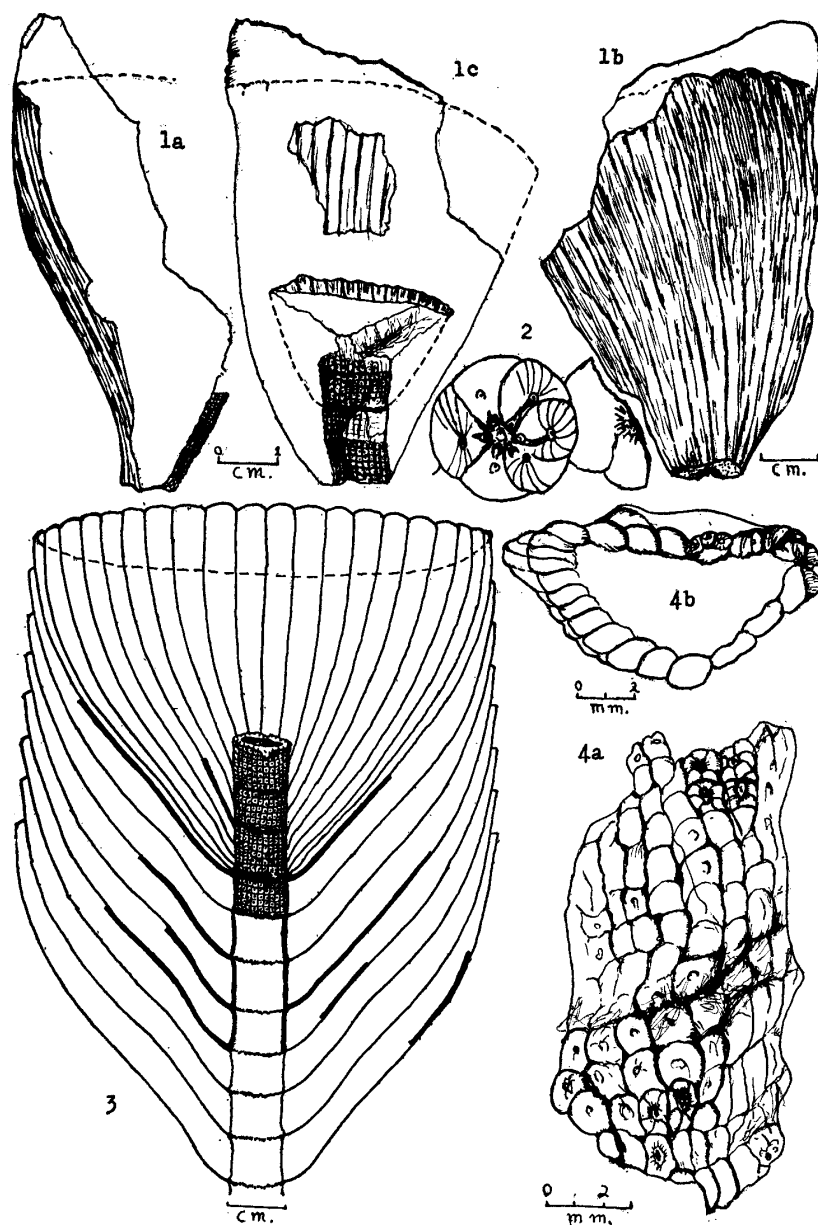
two successive grooves. (4) Leaf-sheath of the main stem is composed of 12-16 leaves, the maximum number of which being constantly 16 and the minimum eight ; it is usually divided into two well-defined opposite coherent lobes, and it is only in the basal region of the main stem that the sheath-lobe is split into separate leaves free down to their bases and pointing downwards. (5) Lateral branch consists of more than seven internodes, the lowermost of which is considerably longer than the next upper one. (6) In the lateral branch the sheath-lobe is not separated into individual leaves even in its basal extremity ; when the branch is immature apical leaves in a whorl are united completely into a single tightly coherent sheath of upturned bottle-shape, provided with a small circular opening at the apex. (7) The leaf-sheath in the branch consists of 8-14 leaves the maximum being generally 14, rarely 16. (8) Sheath-lobe is either oval (Length : Width = 2-2.2), oblong (L : W = 2.5), shortly lanceolate (L : W = 3.0-3.4), or lanceolate (L : W = 4.3-4.5) ; apical margin is truncated with short dents, each of which receives a midrib ; commissural lines are always very distinct, and clearly defined even when the midribs are practically invisible. (9) The leaf is linear or linear-lanceolate with a pointed apex attached firmly to the node by means of a circular disc ; the midrib is distinct, thick, occupying 1/3-1/4 of the maximum width of the leaf, not single but multiple, being composed by several fine striations. (10) All the leaves in a whorl are always of equal size, showing no anisophylly.

(2) Rhizome and Root. — Associated closely with the specimens of *Schizoneura manchuriensis* occur a few remains of rhizome, which are linked by the characteristic longitudinal ribs on the internode with the aerial vegetative shoot. The specimen shown in Pl. 19, fig. 5, is an example of a fair-sized once-branched stem, bearing a small lateral stem with roots and rootlets. The internode of the main stem is 60 mm. long by 5.5 mm. across, traversed regularly by 1.4 mm. distant longitudinal ribs and covered by crowded rootlet-like appendages. On the node are found numerous round scars of branch-base of 1.3–1.6 mm. in diameter, by one of which the branch is attached in continuity to the parent stem. No other scar, large enough to suggest the presence of erect aerial stem, can be seen on the node. The lateral branch is 2 mm. across, and appears also jointed into about 10 mm. long internodes attached by roots at nodes. All of these evidences, however, are far from sufficient to answer the question whether this main stem was prostrated or grown erectly under ground. It is evident that this specimen is preserved lying on a plane making angles of about 40° with the true bedding plane, which may, however, not indicate by itself that it was preserved in its original position of growth. As above said, the main stem is rather thin, provided with numerous branch-scars of equal size around the node, lacking any large scar to indicate the basal scar of the aerial erect stem, all of which seem to suggest that this stem was an erect underground stem rather than the prostrate.

(3) Fructification. — There are seven specimens now at hand, all of which were found in a bed containing nearly nothing but impressoins of foliages, rhizomes and stems of *Schizoneura*. Beside their intimate association in occurrence, these aerial and the fertile shoots are closely linked with each other by their characters, e.g. the large coherent sterile leaf-sheath of the strobilus is built by fusion of leaves just like those of the vegetative aerial shoot; sporangiophores in the internode of the cone, the ridges and furrows of the stem of the aerial shoot, etc. are all superposed in longitudinal rows. These evidences are sufficient to prove that these two types of specimens of the vegetative and the reproductive shoots belong to one and the same plant.

a) Remarks on individual specimens. —

Specimen shown in Pl. 20, figs. 1a, 1b, 1c; Text-fig. 4 (IGPS coll. cat. no. 78083). — These three figures show the front, the side and the back views of a single specimen. This specimen consists of four internodes with clusters of sporangiophores and about four large sterile leaf-sheaths. The sterile leaf-sheath is composed by intimate cohesion of leaves of more than 67 mm. in length and 5 mm. in width at apex; upper margin of the sheath is undulated or with shallow round teeth, each corresponding to each leaf-segment; whole surface of the sheath is penetrated by fine striations of 0.11 mm. distance and much thicker ones, the latter of which evidently represent the sutural lines between leaves. Leaf-segment appears to be given off nearly at a right angle from the cone-axis, but immediately thereafter bent suddenly forwards to make an angle of about 30° to the axis, soon then curves considerably outwards and then again forwards. Thus the resulted leaf-sheath assumes a shallow cup-like form. In this specimen about one half of the total leaves of the sheath are preserved. We have no such well-preserved specimen as to show the complete outline of its leaf-sheath, so that we may doubt if this leaf-sheath is split into



Text-fig. 4. *Manchurostachys manchuriensis*. Specimens nos. 78083, 78084.

Figs. 1a, 1b and 1c are drawn from the specimen shown in Pl. 20, figs. 1a, 1b and 1c, respectively; 1a is the side view of the specimen, showing the curvature of the sterile leaf-sheath; 1b is the back view, showing a large coherent sterile leaf-sheath composed by thorough fusion of all the leaves along sutural lines; 1c is the front view, showing the central fertile axis covered by crowded sporangiophores arranged in superposition in longitudinal rows. Fig. 2 is the upper view of a sporangiophore under its peltate lamina, showing six spores attached to their common axis, $\times 13$. Figs. 4a and 4b are drawn from the specimen shown in Pl. 20, figs. 4a and 4c; 4a is the front view of two internodes, each consists of about seven whorls of sporangiophores; 4b is the view of cross section of the fertile axis, showing about 23 sporangiophores in a whorl. Fig. 3 is drawn mainly from two specimens shown in Pl. 20, figs. 1 and 3; actually preserved parts of both leaf-sheaths and the fertile axis are drawn by thick lines and the restored parts by thin lines, $\times 2/3$.

partial sheath-segments, just like the two opposite lobes in the vegetative leaf-sheath. However, most probably that is not the case as recognized from other specimens e.g. shown in Pl. 20, fig. 2. The central fertile spike as preserved is 33 mm. long with four internodes; sporangiophore has a peltate lamina of about 1.5 mm. in diameter; sporangium is small, and 0.7 mm. in diameter.

Specimen shown in Pl. 20, figs. 3, 4 and Text-fig. 4, fig. 4 (IGPS coll. cat. no. 78084). — In this specimen the central axis as preserved is 55 mm. long, and is divided into seven internodes. Text-fig. 4, fig. 3 shows the restoration of this specimen, drawn with additional data given by the specimen shown in Pl. 20, fig. 1, in which the actually preserved parts are drawn by thick full lines and the restored parts by thin lines. From this figure, the specimen appears to consist of about ten internodes and 11 sterile leaf-sheaths, and accordingly the original strobilus must have been much larger in size. I was fortunate in succeeding to separate the central fertile cylindrical part, shown in Pl. 20, figs. 4a, 4b, 4c, from the specimen shown in Pl. 20, fig. 3 by crushing the rock-matrix into several pieces. This isolated central axis consists of two internodes, each of which bears six to seven whorls of sporangiophores. Pl. 20, fig. 4a and Text-fig. 4, fig. 4a show the front view, in which the internode is about 7 mm. long by 8 mm. across, covered by crowded sporangiophores; sporangiophores are arranged regularly in superposition in longitudinal rows, which are generally separated from each other by a somewhat deep longitudinal groove; the sporangiophore is represented by a simple polygonal disc with a central depression, but often by six sporangia in a group around the central depression (see Text-fig. 4, fig. 2), which possibly shows the feature under the peltate lamina. Fig. 4b in the same plate shows the back view of the same specimen, in which a large shallow depression is seen in the lower end, representing the counterpart of the nodal diaphragm of this cone-axis; fig. 4c and Text-fig. 4, fig. 4b show the view of cross section of the same cone-axis, bearing about 23 sporangiophores in a whorl.

Specimens of spore mass shown in Pl. 20, figs. 9, 10, 11, 12 (*Manchurostachys* slide nos. 4, 5, 6). — These spore masses are obtained mainly from the compressions of sporangia of the specimens shown in Pl. 20, figs. 3 and 5, being prepared by maceration with Schulze's solution. Of them, fig. 9 shows an aggregate of carbonized spores, being almost unaffected by the solution to retain their original feature and composition; figs. 10 and 11 represent the deeply macerated examples to have nearly transparent or light orange to light brown colour in the transmitted light; fig. 12 is the fairly macerated to be translucent or dark brown in colour. All the specimens of the cone now at hand are merely the compressions, imbedded in brown rock-matrix, and consequently the carbonized content of the sporangium is extremely scarce. Thus the materials used for maceration are the mixture of sand and other mineral matters and few fragments of coaly matter, being obtained by scraping the surface substance off the cone-specimens. For detecting, therefore, the spores or the spore mass in thus mixed materials on the slide glass, the pure organic fragments were firstly discriminated from mineral matters under the crossed Nicols of polarizing microscope, and then thus selected organic fragments were examined in the ordinary transmitted light.

b) Conclusion on the fertile shoot. — (1) The fertile shoot consists of the regular

alternation of the interval with clusters of sporangiophores and the completely united large sterile leaf-sheath, the latter of which are inserted at regular intervals of about 5–10 mm. length upon the cone-axis of about 10 mm. in width. (2) The sterile leaf-sheath is magnificent in size, built by complete fusion of long leaves measuring as long as 65 mm. in length and penetrated uniformly by radiated fine striations; this extraordinarily large size of the sterile leaf-sheath appears to suggest that this leaf-sheath was not only the protective organ but also the vegetative one of this fertile shoot during the life of this plant. (3) The fertile shoot appears to be too large in size to be borne terminally on either the main or the lateral stem of any vegetative aerial shoot, because the largest example of the vegetative shoot now at disposal has the lower internodes measuring only 10–17 mm. in width. If so, then this magnificent fertile shoot would have grown on the ground independently from the aerial vegetative shoot, and in direct continuity with its rhizome, just after the manner of some recent *Equisetum*, e.g. *E. arvense* L. (4) Sporangiophores in each whorl number 20–23, which are much more in number than either the branches or the leaves in a whorl of the vegetative shoot. (5) Generally six to seven whorls of sporangiophores are attached upon the interval between every two successive sterile leaf-sheaths, and these sporangiophores in each interval are superposed in vertical rows. (6) Sporangiophore never associates with bract, consisting of a solitary hexasporangiferous peltate lamina and possibly a simple axis; the peltate lamina is polygonal in shape with a diameter ranging from 1.3 mm. to 1.7 mm., attached generally by six sporangia underneath. (7) Sporangium is ovate with a shorter diameter of 0.6–1.0 and a longer one of 1.0 mm. (8) Spore is rounded in shape with a diameter ranging from 10 to 14 μ , most probably homosporous.

II TAXONOMIC POSITION OF *SCHIZONEURA* (*MANCHUROS-TACHYS*) *MANCHURIENSIS*

(1) Comparison with other species of *Schizoneura*

a) Comparison with *Sch. gondwanensis* Feistmantel. — This species was first established mainly based on the materials from the Damuda Group in India, occurring most abundantly in the Raniganj Series. In general features this Indian species is very near to the present Manchurian species, differing only in size of every organ and also in the maximum number of leaves in a sheath. To examine the specimens from the Damuda Group reported by Feistmantel (1880, pp. 61–64, Pls. 1A–10A), the stem attains 35 mm. in width, sheath-lobe measures 25 mm. in width and 90 mm. (rarely 140 mm.) in length, composed of far numerous leaves, maximum number of which being generally 22, rarely 28; in the Manchurian species the sheath-lobe is 10–20 mm. wide and only 30–55 mm. long, and the leaves in a whorl number constantly 14–16 in maximum. Among the Indian species, however, specimens from the Panchet Series reported by Feistmantel (1880, p. 63, Pl. 10A, figs. 1–8) are somewhat smaller in size and the maximum number of leaves in a whorl is 16–18 (rarely 20), and thus they come somewhat nearer to the present species than those from the Damuda Group. The fructification of *Sch. gondwanensis* was first reported by Etheridge (Jun.) (1903) from the New Castle Series in New South Wales under the name

of *Sch. australis* Etheridge. This specific name was later united with *Sch. gondwanensis* Feistmantel by Arber (1905, p. 9), who at the same time reproduced Etheridge's original illustration and described it as follows: "In one of the specimens figured the leaf-bearing axis is terminated by a pair of compact strobili of 2–2.5 cm. in length (Text-fig. 4). Unfortunately, however, the preservation is not sufficiently good to afford any details as to the morphological structure of the cone." From the Text-fig. 4 of Arber, it is noticed that these compact terminal cones appear to be destitute of any sterile bract, and in this respect they differ essentially from *Manchurostachys*. Recently a similar specimen of an isolated cone attached to an incomplete stalk was reported by Srivastava (1954, pp. 76–77, Pl. 3, figs. 22, 23, 24, 25) from the Raniganj Series in India, which was taken by him as "a cone probably belonging to *Schizoneura gondwanensis*." "Impression," according to Srivastava, "of an isolated compact strobilus is roughly elliptical in outline with a broadly pointed apex and a slender stalk at the base. — On the surface of the strobilus (Pl. 3, fig. 23) are seen polygonal or hexagonal discs, about 2 mm. across and closely fitting with one another. — Unfortunately, the information about the sporangia and spores could not be obtained from this strobilus in spite of several efforts." After comparing his cone closely with Etheridge's specimen of *Sch. gondwanensis*, he concluded as follows: "in my specimen there is no indication of the presence of sterile bracts; on the other hand the strobilus is compact. —, the *Schizoneura* type of cones are much closer to *Equisetum* group than the *Phyllothea* type." (Srivastava, 1954, pp. 76–77). Another similar specimen of Equisetaceous cone?, collected also from the Raniganj stage in India, was described by Surange (1955, p. 87, fig. 11), which shows, according to him, "hexagonal impressions of peltate heads of the sporangiophores. They are about 1 mm. in diameter. —. This impression resembles very much to that described by Srivastava (1954) which he had ascribed to *Schizoneura*." Thus it seems rather surprising to find that the Manchurian *Schizoneura* shows on one hand a very close resemblance with *Sch. gondwanensis* in the feature of the vegetative shoot, but on the other differs essentially from the latter in the details of the fertile shoot, consisting of regular alternations of clusters of sporangiophores and a large sterile leaf-sheath. Thus just contrary to the above-cited conclusion of Srivastava's (1954, pp. 76–77) with regard to the fructification of *Sch. gondwanensis*, this Manchurian cone shows a much closer resemblance to *Phyllothea* than *Equisetum*. Moreover in features of the vegetative shoot as well as in the native habitat, *Schizoneura* comes much nearer to *Phyllothea* than either *Equisetum* or *Equisetites*, and it is more natural that *Schizoneura* shows a closer relationship with *Phyllothea* than the latters.

b) Comparison with *Schizoneura paradoxa* Schimper et Mougeot and its fructification (*Aethophyllum*). — This is the type-species of *Schizoneura*, and has been reported from various localities in western Europe in beds ranging from Buntsandstein to lower Keuper. It differs from *Sch. manchuriensis* in either its leaf-sheath consisting of only seven to eight leaves in total or its leaves as well as leaf-sheath being of much larger size. Schimper and Mougeot reported at the same time, when they first established this genus, several specimens of fertile shoot under the name of *Aethophyllum* gen. nov. Later, Schenk (1890, p. 392) regarded these specimens as representing "der obere racemös verzweigte Theil von

Schizoneura paradoxa mit Sporangienähren." The splendid figure of reconstruction of *Sch. paradoxa* with terminal cones of the *Aethophyllum*-type is given by Mägdefrau in his "Paläobiologie der Pflanzen" (1956, p. 213, fig. 199). With respect to their *A. speciosum*, Schimper and Mougeot (1844, p. 40) say as follows: "Fleurs réunies dans des epis allongés, cylindriques, droits et terminant la tige et les rameaux; feuilles florales lancéolées, drites-étalées." Though unfortunately further details of this cone have not been made clear, it is evident that it differs essentially from the cone of *Sch. gondwanensis* in having regular insertion of whorls of lanceolate sterile leaves, and in this character it comes rather nearer to the fructification of either *Manchurostachys* or *Phyllothea*. Thus it is certain that there are in *Schizoneura* at least three types of fructifications, namely of *Sch. gondwanensis* reported by Etheridge (1903), of *Manchrostachys manchuriensis* reported by myself and of *Sch. paradoxa* by Schimper and Mougeot (1844), the former two being of late Permian and the last of early Triassic in age. In the feature of the vegetative aerial shoot, these three species of *Schizoneura* are not so different from one another as are their fructifications. Nearly the same can be seen between *Sphenophyllum* and its various types of fructifications. Thus we come naturally to the conclusion that the genus *Schizoneura*, which is represented by *Sch. gondwanensis*, *Sch. manchuriensis*, and *Sch. paradoxa*, contains at least three distinctive types of fructifications, which suggests that this form-genus *Schizoneura* seems to represent a large taxonomic unit of much higher rank than a mere genus.

c) General remarks on the foliage shoots of typical species of *Schizoneura*.—*Schizoneura* is usually delimited by means of features of the leaf-sheath into individual species. To examine the geological and the geographical distributions of species of the typical *Schizoneura*, the larger form of *Sch. gondwanensis* occurs in India mainly in the coal-measures ranging from the Karharbar through the Barakar to the Raniganj in age: the smaller form of the same species occurs in the same country in the coal-bare Panchet Series; *Sch. manchuriensis* and *Sch. striata* are found in Eastern Asia in the Kobosan and its equivalent coal-bare formations; *Sch. paradoxa* also in coal-less Triassic formations in Europe. In the larger form of *Sch. gondwanensis*, the leaf-sheath of the main stem is generally large and consists of numerous leaves, the maximum number being 22 rarely 28; in the smaller form of the same species, the leaf-sheath is small with its maximum number of leaves of 18 (rarely 20); in *Sch. manchuriensis* and *Sch. striata* it is small in size with the maximum number of leaves of 16 and 12, respectively; in *Sch. paradoxa*, it is large with seven to eight leaves in maximum. If these four species are assumed to have been derived from a common ancestor, represented by the larger form of *Sch. gondwanensis*, this larger form flourished in India throughout the Permian Period and passed into the smaller form of the same species in the early Triassic Panchet age; in the Far East the ancestor probably derived also from the larger form of *Sch. gondwanensis*, would have given rise to *Sch. manchuriensis* and *Sch. striata* in later Permian, in which leaves in a sheath were lessened to only 12-16; in Europe the early Triassic *Sch. paradoxa*, the ancestor of which probably having been derived also from the larger form of the Indian species, retained the larger size of the leaf-sheath unchanged, but reduced considerably its maximum

number of leaves of the leaf-sheath to only seven to eight in total.

(2) Comparison with other genera and families

a) Comparison with *Phyllothea* and its fructification.— Though our knowledge on the anatomical structure and the fructification is extremely limited, *Schizoneura* has usually been placed, though provisionally, in Equisetales, mainly because of its leaves in a whorl being fused into a coherent sheath like those of both *Phyllothea* and *Equisetum*. Of these two members of Equisetales, *Phyllothea* resembles *Schizoneura* more closely than *Equisetum*, and moreover *Phyllothea* occurs mainly in Gondwana land in close association with *Schizoneura*. In the northern hemisphere, too, several regions in Siberia, Europe, etc., have yielded some species of *Phyllothea*. It is, however, quite doubtful if more than 30 known species of the so-called *Phyllothea* are all truly referable to a single natural genus founded on sufficient evidences. For comparison, therefore, of *Sch. manchuriensis* with *Phyllothea*, it seems more preferable to compare mainly their fructifications with each other. There are at least three types of fructification in *Phyllothea* hitherto known as: *Ph. deliquescens*, *Ph. uluguruana*, and *Ph. Rallii*. Among them, those of *Ph. Rallii* Zeiller (1902, pp. 65–69; Pl. V, figs. 11, 11A; Text-figure) was reported from the middle to the upper Westfalian formation of Heraclea, Turkey; its long cylindrical spike consists of alternate verticils of sterile bracts and tetrasporangiferous sporangiophores. As pointed out by Zeiller himself, this fructification coincides in structure with that of the *Calamosstachys*-type of *Calamites*, and on account of this fact, Gothan (1927, p. 150) expressed his opinion to prefer to bring *Ph. Rallii* into *Annularia*. The present writer agrees with this view of Gothan's to remove the fructification of *Ph. Rallii* from those of *Phyllothea*. The second type is the fructification of *Phyllothea deliquescens* (Goeppert), reported by Schmalhausen (1879) from the Permian beds in the Lower Tungusca, Siberia. After re-examination of the specimens sent by Schmalhausen to Strassburg, Solms-Laubach (English translation by Garnsey, 1891, p. 181, fig. 17) gave a splendid drawing and described as follows: "A striated axis with sheaths thoroughly like those of *Phyllothea* bears on the internodes between the sheaths in a lateral position certain small organs, which are exactly like the sporangiferous peltate discs of our *Equiseta*. They lie indeed in numbers all round the axis in the interval between every two sheaths." The third type of fructification is *Ph. uluguruana* Gothan (1927, p. 150, Pl. 18, figs. 6, 7, 8), from the Eccia Series (lower Permian) in East Africa. The strobilus consists of alternations of long interval with clusters of sporangiophores and the sterile leaf-sheath. The sterile leaf-sheath is fused only basally into a sheath and then split into long free teeth; each internode is about 30 mm. long, bearing more than 15 whorls of crowded solitary sporangiophores with polygonal peltate discs. Thus these fructifications of both second and the third types coincide in their major structure almost completely with each other. *Manchurostachys*, too, resembles them closely, but differs in having a large completely fused sterile leaf-sheath. In features of the vegetative shoot, *Schizoneura* and *Phyllothea* are very near, because in these genera the ridges and furrows on the internodes are not alternate but continuous at node from one internode to the next, leaves in a whorl united into a coherent

sheath, leaves are generally very long, being about twice as long as the adjacent internode. Chief distinctions of *Sch. manchuriensis* from *Phyllothea* lie in its leaf-sheath, which is split quite regularly into two opposite lobes, each being composed by fusion of long leaves for nearly the whole of their length. Before comparing with the next genus, some other species must be noted. *Phyllothea Etheridgei* Arber (1905, pp. 26-28, Text-fig. 9) is characterized, according to Arber (1905, p. 27), "by the short free teeth (3 mm. long), and the sheath, clasping at the base, but expanding distally into an open and spreading disc-like structure." This peculiar disc-like leaf-sheath reminds us of the likely coherent sterile leaf-sheath of *Manchurostachys*. Another more noteworthy specimen is the fructification of *Koretrophyllites*, reported by Radczenko (1955) under the name of *K. vulgaris* from the Namurian formation of Kuzbass in Siberia. I am unfortunately not acquainted with the original paper of Radczenko's, but fortunately his drawing is reproduced by Kryshstofovich (1957, p. 471, fig. 428, 3). In this drawing, the long spike appears to consist of regular alternations of the interval with numerous sporangiophores and the sterile leaf-whorl; sterile leaves are long, linear, uninerved and free nearly down to their bases; many whorls of solitary sporangiophores are densely attached on the interval between every two successive leaf-whorls; sporangiophores in each interval are arranged not alternately but in superposition in longitudinal directions. If the interpretation of this drawing of Radczenko's is correct, then the fructifications of *Koretrophyllites vulgaris*, *Phyllothea deliquescens*, *Ph. uluguruana*, and *Manchurostachys manchuriensis* are common in having a long spike consisting of regular alternations of the interval with clusters of bract-less sporangiophores and the sterile leaf-whorl. Chief distinctions among them appear to lie only in degree of fusion of sterile leaves in a whorl, that is in *Koretrophyllites vulgaris* they are nearly free down to their bases, in both species of *Phyllothea* they are fused basally into a shallow sheath and free for their considerable length, and in *Manchurostachys* they are united for nearly their whole length. Geologically and geographically speaking, *Koretrophyllites vulgaris* occurs in the Namurian formation in Kuzbass, *Phyllothea uluguruana* in Ecca (early Permian) Series in East Africa, fructification of *Ph. deliquescens* in the Permian of the Lower Tsunguska, and *Manchurostachys* in the Tsaichia formation (lower part of the late Permian) in Manchuria. To my regret, it is not certain whether the sporangiophore of *Koretrophyllites vulgaris* is tetrasporangiferous as in the fructifications of *Calamites* and *Asterocalamites* or hexasporangiferous as in *Phyllothea*, *Manchurostachys* and *Equisetum*. Moreover it has not been made clear in the fructifications of *Phyllothea* if the sporangiophores on each interval between two successive sterile leaf-sheaths are superposed in longitudinal rows, which, however, may most probably be the case, because of their ribs and furrows on the internode of the vegetative stem being generally continuous through node from one internode to the next. Thus, though some characters are left still uncertain, we can expect here the existence of a distinct series containing *Koretrophyllites vulgaris*, *Phyllothea uluguruana*, *Ph. deliquescens* and *Manchurostachys manchuriensis*. Of them *Koretrophyllites vulgaris* is a plant of Namurian and far older in age than the rest of the Permian, which appears to suggest that the former one might have been one of the ancestors of the latter. There is, however, considerable interruption

of records to prove the presence of any direct phylogenetic relationship between this Namurian plant and the rest separated so remotely in age from each other.

b) Comparison with *Equisetum* and its fossil equivalence (*Equisetites*). — The recent *Equisetum* contains more than 30 species and is widely distributed in the world. But its age of zenith was evidently the Mesophytic Era since the dawn of the Triassic Period. The Paleozoic records of *Equisetites* are extremely meager and incomplete, and entirely unknown in the southern hemisphere, and in this respect *Equisetites* is decidedly different from *Schizoneura* and *Phyllothea*, both of which occur mainly in the later Paleozoic beds of the southern hemisphere. From *Sch. (Manchurostachys) manchuriensis*, too, *Equisetites* differs in many characters as: the cone is terminal, ovoid and entirely destitute of either bract or sterile leaf-sheath; ribs on the internode, leaves, branches when present, etc. are all arranged alternately at successive nodes. Chief resemblances between them are found only in the bract-less solitary hexasporangiferous sporangiophore in the cone and in the coherent leaf-sheath in the foliage. Among the distinctions, the entire absence of either bract or sterile leaf-sheath in the cone in *Equisetum* and *Equisetites* is most essential; in *Equisetum*, however, according to Seward (1898, p. 286), "In abnormal fertile shoots of *Equisetum*, sporophylls occasionally occur above and below a sterile leaf-sheath. Potonié (1896, p. 119, fig. 3) has figured such an example in which an apical strobilus is succeeded at a lower level by a sterile leaf-sheath, and this again by a second cluster of sporophylls. As Potonié points out, this alternation of fertile and sterile members affords an interesting resemblance between *Phyllothea* and *Equisetum*. It suggests a partial reversion towards the Calamitean type of strobilus."

c) Comparison with fertile and foliage shoot of *Calamites*. — In the stem and its medullary cast of *Calamites*, the ridges or vascular bundles on the internode generally alternate at the node, and casts of infranodal canals are seen just below the nodal line, all of which are not met in *manchuriensis* and other species of *Schizoneura*. In the fructification of *Calamites*, either of *Calamostachys* or *Palaeostachya*, only one whorl of tetrasporangiferous sporangiophores is seen between every two successive whorls of the bracts, and no trace of sterile leaf-sheath is inserted to the cone. Among the foliage shoots of *Calamites*, which are generally delimited by feature of leaves in a whorl at the node, *Asterophyllites*, *Annularia*, and *Lobatannularia* are most important. Chief distinctions of these genera from *Sch. manchuriensis* are as follows: in *Asterophyllites* the main stem is twice branched, leaves in a whorl are long, linear and free down to the node; in *Annularia* the penultimate lateral stem bears opposite distichous ultimate branches, leaves in a whorl are spatulate or linear-spatulate in form, free down to their bases and lie in one plane nearly parallel to the axis; in *Lobatannularia*, the leaves in a whorl are just like those of *Annularia* in shape, but markedly anisophyllous and divided into two equal coherent lobes which lie in a plane nearly parallel to the axis. *Neocalamites* which was formerly described as *Schizoneura*, differs from *Sch. manchuriensis* by its leaves in a whorl being free down to their bases. Thus *Sch. (Manchurostachys) manchuriensis* is evidently very remote in feature of either fertile or vegetative shoot from any forms in *Calamites*, and in this connection the following view of Surange's (1955, p. 83) should be remembered as: "In the

Glossopteris flora of the southern hemisphere Equisetales is represented by two genera, *Schizoneura* and *Phyllothea*, as against *Calamites* and allied genera in the northern hemisphere."

(3) Conclusion on the taxonomic position of *Schizoneura* (*Manchurostachys*) *manchuriensis*

The Class Articulatae is generally subdivided into the following five orders (Reimers, 1945, pp. 280–281) as: Hyeniales, Pseudoborniales, Sphenophyllales, Calamitales and Equisetales. The last-mentioned order is characterized, according to Reimers (1954, pp. 281–282), by "Blätter einfach, mit je einem Leitbündle, nur bei fossile Formen frei, bei den rezenten innerhalb des Blattquirls weit hinauf zu einem zylindrischen Gebilde verwachsen —. Sporophyllstände nur bei fossilen Formen mit sterilen Zwischenwirteln, bei den rezenten nur aus fertilen, schildförmigen Sporophyllen mit meist 8 anatrophen Sporangien zusammengesetzt. Isospor." In this order is placed by the same author only one family — Equisetaceae, which contains such three genera as: "Fossile Arten (*Equisetum*) bereits im Karbon, noch im Keuper das baumförmige *E. arenaceum* mit seitlichen, büschelig gestellten Sporophyllständen. — *Phyllothea* im Unterkarbon und Perm der Gondwana-Länder, im Buntsandstein eine Art auch in Europa; Blätter nur am Grunde verwachsen; Sporophyllstände mit je 1 sterilen Wirtel zwischen einer Anzahl fertiler. — *Schizoneura* im Perm meist der Gondwana-Länder, Blätter am Grunde verwachsen, in 2 oder mehr gegenständige Segmente gespalten." (Reimers: 1954, p. 286). It is of course only provisional to place *Schizoneura* within Equisetaceae, because our knowledge on the reproductive organs of *Schizoneura* is too insufficient. By the present study, one distinct type of the fructification of *Schizoneura* has been made clear, in which the cone consists of a regular alternation of clusters of bract-less hexasporangiferous sporangiophores and a large coherent sterile leaf-sheath, and by these characters it is distinguishable easily from any types of the fructification of *Calamites*, in which only one whorl of tetrasporangiferous sporangiophores is seen between every two successive whorls of bracts. In Articulatae, whether the sporophyll is bract-bearing or bract-less has been taken as one of the most fundamental distinctions; the bract is regarded as a sterile branch of a sporophyll and has nothing to do with the large sterile leaf-sheath of the cone of *Phyllothea* and also of *Sch. manchuriensis*, which might have most probably been the vegetative organ of the reproductive shoot. With this respect, we should cite the comprehensive view of Hirmer's (1927, p. 468) as: "Durch verhältnismässig einfachere Blütentypen sind die ältesten und jüngsten Formen charakterisiert. So gilt für die beiden Protoarticulaten-Gattungen (*Calamophyton* und *Hyenia*), für *Astreocalmites* und *Autophyllites* und wieder für *Equisetites*, *Equisetum* und *Phyllothea*, dass ihre Blüten aus unverzweigten peltaten Sporophyllen gebildet sind. Dagegen ist *Pseudobornia*, *Cheirostrobis*, *Sphenophyllum* und den *Calamiten*-Blüten: —, gemeinsam, dass in ihren Blüten Quirle von fertilen, mannigfach gebauten, zum Teil verzweigten Sporangienträgern mit solchen steriler Brakteen abwechseln, was zum mindesten bei den allermeisten, wenn nicht allen auf Zerteilung des sporophylls in fertile Abschnitte (Sporangiophore) und in sterile Brakteen beruht." Thus it is clear

that *Equisetites*, *Equisetum* and *Phyllothea* can safely be grouped up into one series, which Reimers (1954) called Equisetaceae, but which most of the taxonomists call Equisetales containing two families — Equisetaceae and Phyllotheaceae. The present Manchurian *Schizoneura* is safely referable to Equisetales, by its bract-less peltate sporangiophores of the cone.

Schizoneura manchuriensis comes much nearer to *Phyllothea* than to *Equisetum* and *Equisetites*, because the former two are common in having firstly the cone composed of alternation of clusters of bract-less sprangiophores and of large sterile leaf-sheath and secondary ridges and furrows on the internode of the stem are continous at node from one internode to the next. On the contrary *Equisetum* and *Equisetites* are entirely destitute of sterile leaf-sheath in the cone and ridges or vascular bundles of the stem alternate at the node. Further *Schizoneura* and *Phyllothea* are essentially the plants of the late Paleozoic Gondwana land, and both are considered to have originated in the southern hemisphere, whereas *Equisetites* mainly occurs in the Mesozoic formations and possibly might have originated in the northern hemisphere. Thus it is quite reasonable to conclude that *Sch. manchuriensis* shows much closer resemblance to *Phyllothea* than *Equisetites*. There are four species hitherto known, each of which is characterized by the fructification having clusters of bract-less sporangiophores between every two sterile leaf-sheaths. They are *Koretrophyllites vulgaris* Radczenko from the Namurian formation in Kuzbass, *Phyllothea uluguruana* Gothan from the Ecca Series (early Permian) in East Africa, *Ph. deliquescens* (Goeppert) from the Permian in the Lower Tunguska, and *Schizoneura* (*Manchurostachys*) *manchuriensis* Kon'no from the Tsichia formation (lower part of the late Permian), all of which may be grouped up into one distinct series, characterized by large sterile leaf-whorls inserted at regular intervals upon the cone-axis

There are, however, another type of fructification in *Schizoneura*, differing entirely from that of *Sch. manchuriensis*, the one of which is of *Sch. gondwanensis* reported from the New Castle Series (late Permian) in Australia, and the other is of *Sch. paradoxa* (*Aethophyllum*) from Buntsandstein in Vosges. In the Australian species, the strobilus is developed terminally on the stem, ovoid in shape and entirely destitute of either bract or a sterile leaf-sheath, and in these characters it shows rather a close resemblance to *Equisetum* and *Equisetites* as pointed out by Arber (1905), Srivastava (1954) and others. On the other hand, in *Aethophyllum*, though it is also developed terminally on the main or the lateral stem as in some of *Equisetum*, the strobilus differs essentially from those of *Sch. gondwanensis* and *Equisetites* in having numerous whorls of long lanceolate bracts (or may be sterile leaves) upon it. Though nothing has been reported about the further detailed structure of the cones of both *gondwanensis* and *paradoxa*, it is certain that a mere form-genus, *Schizoneura*, contains at least three distinct types of fructifications, separated widely from one another as: the first resembling *Equisetum*, the second coming very near to *Phyllothea*, and the third being not comparable with either of the former two, but showing an appearance of some Calamitean fructification. It seems quite strange to find that the cone of *Sch. gondwanensis* is in structure nearer to the foreign *Equisetites* than *Phyllothea*, which was a common plant indigenous to Gondwana land and always associated intimately with

Schizoneura. How to interpret these divergent criteria is indeed a perplexed question. In some form-genus, e.g. *Cladophlebis* in the Mesozoic Era, many species were later transferred by subsequent discovery of the fertile specimens into more reasonable genus. However, with respect to the Paleozoic plants of Articulatae, the matters seem quite different. Citing again the view of Hirmer (1927, p. 468), in Paleozoic Articulatae "Gegenüber der Einförmigkeit der Verhältnisse in Sprossbau und Beblätterung ist die Morphologie der Blüte eine sehr mannigfaltige;". One of the best examples of it can be seen in *Sphenophyllum* and its manifold fructifications. In fact, such three species of *Schizoneura* as *gondwanensis*, *manchuriensis*, and *paradoxa* resemble in features of their vegetative shoot so closely with one another that it is by no means possible to bring them into separate genera, because they have such characteristics in common as: the surface of the internodes is traversed by regular ridges and grooves, which are continuous and not alternate in their course from one internode to the next; the leaf-sheath is large and consists of two opposite coherent lobes of equal size; the sheath-lobe is composed by intimate fusion of long leaves for nearly the whole length along marked commissural lines; leaf is much longer than the adjacent internode and the midrib is not single but multiple consisting of several longitudinal striations. (Wills: 1910, p. 271). To draw any conclusion from these criteria, the available evidences are too insufficient, because above all the fructification of *Sch. gondwanensis* has been known by only one or two detached specimens, in which nothing has been known as to either the inner detailed structure of the cone or the feature of the stem below the terminal cone, and with *Aethophyllum* nearly the same can be said. Thus all we can say at present is that the typical *Schizoneura*, represented at least by such three species as *gondwanensis*, *manchuriensis* and *paradoxa*, contains various types of fructification varying in a wide range in the structure. In this connection, *Schizoneura* stands in sharp contrast with *Equisetites*, which has been found in strata ranging from the late Carboniferous to the Tertiary, and at least since the middle Triassic period the major plan of structure of the cone has persisted practically unchanged up to the recent days. In this meaning *Schizoneura* should be sharply separated from *Equisetites*. Thus *Schizoneura* is sure to represent a large taxonomic unit of much higher rank than a mere genus, at least so be ranked as an independent family to be called *Schizoneuraceae* in Equisetales.

III GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF *SCHIZONEURA* AND OTHER ELEMENTS OF GONDWANA FLORA IN CATHAYSIAN LAND

More than half a century ago, Arber said (1905, pp. xxiii-xxiv) as follows: "in the rocks of Gondwana land the genus *Calamites* is unknown. We have in its place two other representatives of the same group, *Schizoneura* and *Phyllothea* —. In *Schizoneura* we have a more distinct type, and one almost entirely confined to India during the Permian-Carboniferous period. — We may regard *Schizoneura*, unlike *Phyllothea*, as essentially of Indian origin, where it first appeared in the earlier *Glossopteris*-bearing series, and later spread to more distant regions." Since then our knowledge of *Schizoneura* has been much extended, and about seven species have been known as: *Sch. Waldei* Zeiller, *Sch. gondwanensis*

Feistmantel, *Sch. africana* Feistmantel, *Sch. striata* Kawasaki et Kon'no, *Sch. manchuriensis* Kon'no, *Sch. paradoxa* Schimper et Mougeot and *Sch. ferganensis*. Of them, the two last-named species occur only in the Triassic System, and all of the rest mainly in the Permian. (see Jongmans: 1922, pp. 681–692). Both Asiatic species — *striata* and *manchuriensis* resemble very closely *Sch. gondwanensis*, the latter of which is the most typical and extensively distributed species in the *Glossopteris*-flora and is characterized by the leaf-sheath being usually split into two equally opposite coherent lobes, each consisting by intimate cohesion of very long leaves for near their whole length. *Sch. gondwanensis* occurs in various Permian strata as: in India in beds ranging from the Karharbari, through Barakar and the Raniganj up to the Panchet in age; in Australia in the New Castle series, which was first named *Sch. australis* by Etheridge and later brought into this Indian species by Arber (1905); in Madagascar *Sch. cf. gondwanensis* occurs in the Sakoa and its overlying Sakamera formation (Eotriass and Néopermien) (Besaire: 1952, pp. 181–183); in Africa in the upper Ecca series of the Zambeze area (Dixey: 1929), in the upper Karroo of Rhodesia (Bond: 1952, p. 216); in Brazil in the Tubaras formation (Martins: 1952, p. 281) (Dolianiti: 1952, pp. 294–295), etc. Recently repeating the above-cited view of Arber, Surange said (1955, p. 83) as: “In the *Glossopteris* flora of the southern hemisphere Equisetales is represented by two genera, *Schizoneura* and *Phyllothea*, as against *Calamites* and allied genera in the northern hemisphere. — It (*Schizoneura*) is regarded as essentially of Indian origin (Arber, 1905).” Thus *Schizoneura* occurring in Europe and Siberia has been regarded as the descendants of the immigrants from the Gondwana land. In Europe *Sch. paradoxa* has been known from the early to the late Triassic strata in various regions and *Sch. ferganensis* from the upper Madygen formation in Central Asia. The Permian records of *Schizoneura* in the northern hemisphere but India has been extremely meager and incomplete, e.g. ? *Sch. gondwanensis* from the late Permian in the Petchora basin, *Sch. sp.* in the late Permian either in the Kusnetz basin or in Ussuriland, until *Sch. striata* and *Sch. manchuriensis* have been reported by Kawasaki and the present writer. Further in Eastern Asia a noteworthy specimen was reported under the name of ? *Schizoneura gondwanensis* from the Yenchang formation (Keuper-Rhaetic) by P'an (1936, p. 13, pl. IV, figs. 7,7a), which was recently, in my opinion, incorrectly transferred to *Neocalamites carcinoides* by Sze (1956, p. 121).

With respect to the mixing of elements of the *Glossopteris*-flora into floras of the northern hemisphere, Krishnan says (1954, pp. 13–14) as follows: “It (*Glossopteris*-flora) is supposed to have originated in Antarctica and spread over the rest of Gondwana land therefrom. — At the later date, in the Middle and Upper Permian, the *Glossopteris* flora came into contact with the Kuznetz flora in Central Asia and Turkestan, with the Euramerica flora in East Africa and Rhodesia, and with the Cathaysian flora in New Guinea.” Jongmans (1940, pp. 263–274) reported from New Guinea the occurrence of *Vertebraria* sp. in one locality and in the other a small flora with an appearance of the Cathaysia-flora, saying as; “Jedenfalls zeigen die Floren beider Fundstellen, dass man es in diesen Gebiete mit einer Mischung von Elementen der Cathaysia-Flora und der *Glossopteris*-Flora zu tun hat.” If so, then we can expect a migration, possibly northwards,

of the *Glossopteris*-flora into the Cathaysian land through the passageway of New Guinea. These plant-bearing beds in New Guinea were correlated by Jongmans approximately to those of Djambi in Sumatra, which are evidently of Artinskian age. It seems quite difficult to interpret the facts that the Djambi-flora is completely destitute of the Gondwana elements, whereas New Guinea has yielded a splendid specimen of *Vertebraria* sp. However, we should remember that the *Vertebraria*-bearing beds may not be exactly contemporaneous with the other beds containing the flora of Cathaysian affinity, because the two fossil-localities, according to the index-map of Jongmans's (1940), are separated by about 10 km. distance. If the *Vertebraria*-bearing beds be somewhat considerably younger in age than the other beds, *Vertebraria* might have migrated into New Guinea at an age later than the Artinskian, as in the case of *Schizoneura* occurring in the lower beds of the late Permian in Eastern Asia. To trace the intermingling of elements of the *Glossopteris* flora with the Cathaysian flora, *Schizoneura*, *Rhipidopsis*, etc. may be most useful. Of them *Schizoneura* is surely most important, but unfortunately it has been known only from two localities, and *Rhipidopsis* shall be chosen in place of it. After detailed study of the rich flora in Central Shansi, Halle (1927, p. 289) selected his *Rhipidopsis lobata* as the most significant example of Gondwana elements in the Chinese Permian, saying as: "It is not identical with any species from the Gondwana or the Angara flora, but the genus represents a typical and important constituents of those floras." *Rhipidopsis* is a well-defined genus, characterized by the large petiolate oval leaf with lamina split deeply into several obcuneate or obovate segments of markedly different form and size. (Seward: 1919, p. 90). *Rhipidopsis* occurs in India in the Damuda System ranging from the Barakar to the Raniganj in age; in Argentina in the Permo-Carboniferous strata; in the Angaraland mainly in the upper half of the Permian, e.g. Petchorian in the Pecthora basin, Koltchugino Series in the Kusnetzk basin, Tungusian Series in Ussuriland, plant-bearing zone C in the Nanshan region in China; it also occurs in the upper part of the Balakhonka Series in the Kusnetzk basin. The records of *Rhipidopsis* in the Cathaysian land are as follows: 1) *Rh. lobata* Halle from the upper Shihhotze Series by Halle (1927, pp. 192-194, Pl. 54, fig. 27); 2) *Rh.* spp. from Kaishantun-flora-bearing beds by Kon'no, (1948, not figured); 3) *Rh. gondwanensis* Seward from the Kobosan Series, North Chosen by Kawasaki (1934, pp. 222-224, Pl. 87, fig. 263); 4) *Rh. densinervis* Feistmantel from the Kobosan series, North Chosen by Kawasaki (1934, pp. 224-225, pl. 87, fig. 264); 5) *Rh. baieroides* Kawasaki et Kon'no from the Kobosan Series, North Chosen, by Kawasaki and Kon'no (1932, p. 41, Pl. 101, figs. 9-10); 6) *Rh. baieroides* Kawasaki et Kon'no from the upper part of the Tofenkou formation in Honan, Central China by P'an (1937, pp. 266-268, pl. 3, figs. 1-3, 3a; pls. 4, 5). Among them, the last-mentioned specimens of P'an are most noteworthy, because it represents the southernmost record of *Rhipidopsis* hitherto known. Recently Sze (1953, pp. 84-85, Pl. 62, fig. 6; Pl. 68, fig. 2) reported these specimens under the name of *Pseudorhipidopsis baieroides* P'an, but such substitution of generic name is in my opinion quite incorrect. Thus these records of both *Schizoneura* and *Rhipidopsis* appear to be sufficient to prove that the elements of the *Glossopteris*-flora were undoubtedly mingled in the Cathaysian flora at least in Central and Northern China as well as in Korea.

However, with respect to *Rhipidopsis* reported by Kawasaki and Kon'no (1932), Jongmans and Gothan (1934, p. 63) expressed their view as "Kawasaki hat aus der Koreanischen *Gigantopteris*-Flora das Vorhandensein von *Sphenophyllum speciosum* Royle und von zwei *Rhipidopsis*-Arten angegeben. Man könnte in dem Vorhandensein dieser Arten eine Einmischung von Gondwana-Elementen, wenigsten im nördlichen Teil der *Gigantopteris*-Flora, erblicken, wenn die Bestimmungen zweifellos wären, was aber unser Meinung nach nicht der Fall ist." In 1934, after detailed study of the flora of the Heian System in Korea, Kawasaki (1934, pp. 265–270) concluded in this connection as follows: "In the Jido flora no characteristically Gondwana species is known, which is a remarkable contrast to the superposing Kobosan Series. — The species of the Kobosan flora, which have been identified with, or closely resemble, those of the Gondwana plants, are as follows:— *Schizoneura gondwanensis* (*S. striata*), *Phyllothea australis* (cf.), *Sphenophyllum speciosum*, *Taeniopteris spatulata*, *T. spatulata* var. *major* (*T. macrospatulata*), *T. howardensis* (*T. brevispatulata*), *Cordaitea Stoliczkanus* (cf.), *Rhipidopsis gondwanensis*, *R. densinervis*. — Thus the Kobosan flora is composed partly of the Mesozoic plants of the far distant Gondwana. — Jido flora was changed by disappearance of those plants unable to withstand the aridity and by new ones and new comers of Gondwana elements migrated northwards." Against this view of Kawasaki's, Jongmans (1937, pp. 359–360) again repeated his former view that "So, as far as we know at present there is no proof of any mixing of these floras. — So we can conclude that the Cathaysia (*Gigantopteris*)-flora has no relation with the real Gondwana-flora of the southern hemisphere, and that in the northern hemisphere there is no proof of any transition into a typical Gondwana-flora in later Permian or Triassic time." It was, however, immediately thereafter that Jongmans (1940) himself reported on the occurrence of a specimen of typical *Vertebraria* sp. in New Guinea. Out of nine species given by Kawasaki (1934) as elements of the Gondwana-flora, *Schizoneura striata* Kawasaki et Kon'no is most important, but this species was established in 1932 on poor material consisting of only three fragmental specimens. Fortunately, the specimens of *Sch. manchuriensis* now at disposal amount to more than 100 in number, by which this species of *Schizoneura* is well founded and the mixing of this essential member of the *Glossopteris*-flora into the Cathaysian flora is substantially authenticated. As seen above, the occurrence of *Schizoneura*, *Rhipidopsis* and other elements of the *Glossopteris*-flora in Eastern Asia is restricted to the Kobosan and its equivalent series in China and Korea. The oldest strata yielding these Gondwana elements are the Kaishantun-flora-bearing beds, cropping out at about lat. 42°42' N. and long. 129°31' E. The Kaishantun flora, according to the study of the present writer (1948, pp. 102–103), is composed mostly of the typical Cathaysian floral elements as *Gigantopteris nicotianaefolia*, *Lobatannularia heianensis*, *Emplectopteris triangularis*, *Neuropteridium* spp. etc. and partly of the exotic forms as *Brongniartites* sp. and *Rhipidopsis* spp. By evidences of this flora as well as the fauna found in a little lower horizon indicating the *Yabeina*-zone (Minato: 1942; Noda: 1956), the Kaishantun-flora-bearing beds were correlated by the present author to the lowermost part of the Tsaichia formation in the Penchiu coal-field. The Tsaichia formation is correlated approximately to the Kazanian stage. As pointed out by Kawasaki (1934) and

others, the Jido and its equivalent formations (Artinskian and Kungurian) in both Korea and China are entirely destitute of the Gondwana elements, and accordingly the age of coming into existence of the Gondwana elements in the Cathaysian land seems to fall into the interval between the Kungurian and the Kazanian, which is approximately the age of the Tungwu Revolution of Lee (1939, pp. 149–152) in Central China.

As is well known, the mingling of the Gondwana floral elements in the Permian Angara flora was formerly too strongly emphasized, but the majority of its plants which had been referred to *Glossopteris*, *Gangamopteris*, etc. were later substituted for *Pursongia*, *Zamiopteris*, *Angaropteridium* and other genera and species, peculiar to the Angara flora. As to the origin of these close apparent resemblance in feature of both Gondwana and the Angara flora, Kryshstofovich (1937, pp. 87–) stated that in the later Paleozoic Era there were two phytopaleogeographical zones having similar temperate climatic condition: the one the Tungusian phytogeographical zone with the flora of *Psygmoephyllum* and *Neurogangamopteris*, and the other the Gondwanian with the *Glossopteris*-flora; and mainly owing to their common edaphic and climatic condition on one hand, and on the other to their common Devonian and the lower Carboniferous ancestors, there gave rise to, between these Tungusian and the Gondwanian floras, the remarkable common feature of the flora as a whole and also the great morphological similarity of their respective plants. Thus we are now confronted with a perplexed question whether the close similarity in morphology seen between respective plants of the Angara and the Gondwana flora, is to be considered as fundamental or accidental. And so far as this question is left open, such doubtful genera and species should not be used for tracing the mutual floral relationship between the Cathaysian and the Gondwana flora.

Whether most of the above-listed Gondwana elements given by Kawasaki (1934) may be left still in doubt, *Schizoneura manchuriensis* and *Sch. striata* are safely referable to the typical *Schizoneura* of the Gondwana flora, I am sure. The evidence of these two species of *Schizoneura* seems to be sufficient to prove that the typical Gondwana floral elements were actually existing in the Cathaysian land at least in the Kazanian age. However, it is yet uncertain whether these *Schizoneura* came across the Tethys sea directly into Cathaysia or migrated first into Angara land and then to Cathaysia by their southward re-migration therefrom. The localities which have yielded the specimens of the Asiatic *Schizoneura* lie far widely separated from the Gondwana land, and on the contrary very near to the boundary between two Asiatic floras of Angara and Cathaysia in the later Permian, running from the point just between Vladivostok and Kaishantun along about lat. 43° N. westwards. (see Kobayashi: 1956. Text-fig. 17; Vakhrameev: 1957, fig. 2). The mixing, however, of the Angara floral elements in the Cathaysian flora is very insignificant even in the northern marginal regions e.g. North Korea (see Kawasaki: 1934, pp. 275–277; 1939, pp. 32–34); Kaishantun (Kon'no: 1948, pp. 102–103); Central Shansi (Halle: 1927 pp. 280–287), etc. In Angara land *Schizoneura* has not been known from the lower half of the Permian even in the well-surveyed Kusnetzk basin, so far as I am aware, though some doubtful specimens of the same genus were reported from the late Permian in a few regions as above said. Moreover the close morphological resemblance of the

Asiatic *Schizoneura* to the Indian *Sch. gondwanensis* appears to suggest strongly their close mutual phylogenetic connection. All of these evidences seem to point rather to the direct migration of *Schizoneura* into Cathaysia instead of via Siberia. We have, however, no criteria at present to conclude, through which of the passageways of Kashmir and New Guinea the migration took place. We can therefore say only tentatively that these Asiatic species of *Schizoneura* might have come into existence, possibly by eastward migration from the west, in the northern Cathaysia in the age ranging from Kungurian to Kazanian, when the large geosynclinal seas, stretching from the present Tianshan and Kuenlun Mts. eastwards to the Nanshan area, were extensively retreating to result in the extensive sedimentation of the Loping and its equivalent series in China and Korea throughout.

BIBLIOGRAPHY

- Arber, E.A.N. (1902) : On the Clarke collections of Fossil Plants from N.S. Wales. Quart. Jour. Geol. Soc., Vol. 58, No. 16.
- . (1905) : Catalogue of the fossil plants of the *Glossopteris* Flora in British Museum. A monograph of the Permo-Carboniferous Flora of India and the Southern Hemisphere, London.
- Besaire, H. (1952) : Les formations de Karroo a Madagascar. Symp. Sér. Gondwana, Alger, pp. 181-186.
- Bond, G. (1952) : The Karroo System in southern Rhodesia. Symp. Sér. Gondwana, Alger, pp. 209-223.
- Dixey, F. (1929) : The Karroo of the Lower Shire-Zambézi area. XV Cong. Géol. Intern. Pretoria.
- Dolianiti, E.A. (1952) : La flore fossile du Gondwana au Brésil d'après sa position stratigraphique. Symp. Sér. Gondwana, Alger, pp. 285-301.
- Feistmantel, O. (1880) : The flora of the Damuda-Panchet Divisions. Foss. Flor. Gond. Syst., Vol. 3, pt. 2.
- Gothan, W. (1927) : Foss. Pfl. a. d. Karruschichten d. Umgebung d. Ulugurugebirge in Deutsch-Ost-Afrika. Palaeontogr., Suppl. 7, 2 Reih. Teil 1, Lief. 3, pp. 146-152.
- Halle, T. G. (1927) : Palaeozoic Plants from Central Shansi. Palaeont. Sin. ser. A, Vol. 2, fasc. 1, Peking.
- . (1935) : On the distribution of the late Palaeozoic floras in Asia. Geogr. Ann., Sven Heden, pp. 106-111.
- Jongmans, W. J. (1922) : Fossilium Catalogus 2 Plantae Pars 9, Equisetales, Berlin.
- . (1940) : Beiträge zur Kenntnis der Karbonflora von Niederländisch Neu-Guinea. Mededeelingen behoorende by het Jaarverslag, Geol. Bureau Heerlen, pp. 263-274.
- . (1943) : Das Alter des Karbon- und Permflora von Ost-Europa bis Ost-Asien. Palaeontogr. Bd. 57, Ab. B, pp. 1-58.
- et W. Gothan (1935) : Die paläobotanischen Ergebnisse der Djambi-Expedition 1925. Jaarb. Mynwezen in Nederl. Indië, 1930, Verhandl., pp. 71-201.
- Kawasaki, S. (1934) : The Flora of the Heian System, pt. 2, Text. Bull. Geol. Surv. Korea, Vol. 6, No. 4.
- . (1939) : Addition to the Flora of the Heian System. Bull. Geol. Surv. Korea, Vol. 6, pt. 5.
- et E. Kon'no (1932) : The Flora of the Heian System, pt. 3. Bull. Geol. Surv. Korea, Vol. 6, No. 3.
- Kobayashi, T. (1956) : Geology of Eastern Asia (in Japanese). Tokyo.
- Kon'no, E. (1942) : On *Schizoneura* from the Penchiu coal-field and its geological significance (in Japanese). Jour. Geol. Soc. Japan, Vol. 49, No. 585, pp. 238-239.
- . (1948) : Stratigraphical and Palaeobotanical studies in the Permian System in the

- Penchihi coal-field and Kaishantun, Chientao District, in Manchuria (in Japanese). Jour. Geol. Soc. Japan, Vol. 53, Nos. 622-627, pp. 102-103.
- Kryshstofovich, A.N. (1937) : Phytogeographical Zones and Stratigraphy of the Upper Paleozoic. Abstracts of papers of International XVII Geological Congress, U.S.S.R. pp. 87-.
- (1957) : Paleobotanika 4th edition, Leningrad.
- Lee, J. S. (1939) : Geology of China.
- Mägdefrau (1956) : Paläobiologie der Pflanzen 3te Auflage, Jena.
- Martins, E.A. (1952) : Les Systèmes de Gondwana dans l'État du Rio Grand do Sul, Brésil. Symp. Sér. Gondwana, Argel, pp. 279-284.
- Minato, M. (1942) : On the geological age of the Toman Formation. Bull. Geol. Inst. Manchuria, No. 106.
- Noda, M. (1956) : Stratigraphical and Palaeontological Studies of the Toman Formation in the Kaishantun and Kamisanbo Districts. Rep. Earth Sci. Dep. Gen. Educ., Kyushu Univ., Vol. 2, pp. 1-22.
- P'an, C.H. (1936) : Older Mesozoic Plants from North Shensi. Palaeont. Sin., ser. A, fasc. 2, pp. 13-14.
- (1937) : Note on Kawasaki and Kon'no's *Rhipidopsis brevicaulis* and *Rh. baieroides* of Korea with Description of similar forms from Yühsien, Honan. Bull. Geol. Soc. China, 16, pp. 261-268.
- Schimper, W. Ph. et A. Mougeot (1844) : Monographie des plants du grès bigarré de la chaîne des Vosges, Leipzig.
- Seward, A. C. (1898, 1919) : Fossil Plants, Vols. 1, 4, Cambridge.
- Solms-Laubach, H. Graf zu (1891) : Fossil Botany (English translation by H. E. F. Garnsey), Oxford.
- Srivastava, P.N. (1954) : Studies in the *Glossopteris* flora of India — 1. Some new fossil plants from the Lower Gondwanas of the Raniganj coalfield, India. The Palaeobotanist, Vol. 3, pp. 70-78.
- Surange, K.R. (1955) : Studies in the *Glossopteris* flora of India — 2. Equisetales from the Raniganj coalfield. The Palaeobotanist, Vol. 4, pp. 83-88.
- Sze, H.C. (1953) : Illustrated Palaeozoic Flora of China. Acad. Sin. Sci. Press.
- (1956) : Older Mesozoic Plants from the Yenchang Formation, Northern Shensi. Palaeont. Sin. N.S.A. No. 5.
- Vakrameev, V. A. (1957) : Izvestiya Akad. Nauk. SSSR. ser. geol. no. 11.
- Walkom, A.B. (1937) : A brief review of the relationships of the Carboniferous and Permian floras of Australia. Comp. Rend. deuxième Cong. Strat. Carbonif. (Heerlen) 1935, 3, pp. 1335-1342.
- Wills, L. J. (1910a) : The fossiliferous Lower Keuper rocks of Worcestershire. Proc. Geol. Assoc. Vol. 21, pp. 249-288.
- (1910b) : Notes on genus *Schizoneura* Schimper and Mougeot. Proc. Cambridge Phil. Soc., Vol. 15, pp. 406-410.
- Yabe, H. et R. Imaizumi (1946) : Plant-bed with the Cathaysian Flora of Kaizantung, Kantôshô, Manchuria, and its Relation to the Marine Permian Deposits. pt. 2. Proc. Jap. Acad., Vol. 22, No. 7, pp. 218-224.
- Zalessky, M. D. (1938) : Schéma général d'une divisions des dépôts continentaux Carbonifériens Permians du Bassin de Kousnetz d'après leur flore fossile. Comp. Rend. 2 Cong. Heerlen Tome 3, pp. 1663-1685.
- et H. Th. Tschirkowa (1937) : Phytostratigraphische Untersuchungen im Bereich der Kohlenführenden Schichten der Permischen Becken von Kusnezsk und von Minussinsk in Siberien. Palaeontogr., Vol. 82, Abt. B, pp. 172-203.
- Zeiller, R. (1899-1902) : Étude sur la flore fossile de Bassin du houiller d'Héraclée. Mém. Soc. Géol. France, Paléont., Mém. 21, Vol. 8, fasc. 4, pp. 1-91.



PLATE 16

Schizoneura manchuriensis Kon'no

(Fig. 5, $\times 2$; all the rest, $\times 1$)

- Fig. 1. Middle part of the main stem, showing longer leaves, 62 mm. in length which is 2.4 times as long as the internode. IGPS coll. cat. no. 78075.
- Fig. 2. Lower part of the main stem of rather small size, showing the lowermost leaf-sheath split into free individual leaves pointing backwards and then reflecting. IGPS coll. cat. no. 78075.
- Fig. 3. Type specimen ; middle and apical part of the main stem, showing both internodes and the sheath-lobes reducing rapidly their length and width towards the apex, where leaves in a whorl appear to be fused into a very small coherent sheath. IGPS coll. cat. no. 78076.
- Fig. 4. Apical part of a stem. IGPS coll. cat. no. 78081.
- Fig. 5. Thoroughly fused apical leaf-sheath of the immature branch of the specimen shown in Pl. 19, fig. 3b. IGPS coll. cat. no. 78071.

PLATE 17

Schizoneura manchuriensis Kon'no

(all, $\times 1$)

- Fig. 1. Lanceolate sheath-lobe of the stem. IGPS coll. cat. no. 78079.
- Fig. 2. Apical end of a stem, showing rapidly reduced internodes and the leaf-sheaths, apparently terminating in a very small coherent leaf-sheath. IGPS coll. cat. no. 78082.
- Fig. 3. Apical part of the large main stem, showing rapidly shortened five internodes ranging from 30 mm. to 9 mm. in length ; the lower leaf-sheath consists of 16 leaf-segments. IGPS coll. cat. no. 78077.
- Fig. 4. Middle part of the large main stem, showing the thick multiple midrib of the leaf-segment, consisting of six to seven longitudinal parallel striations. IGPS coll. cat. no. 78074.
- Fig. 5. Main part of the lateral branch, with the thin and slightly flexuous axis and oblong thoroughly fused sheath-lobes. IGPS coll. cat. no. 78078.



PLATE 18

Schizoneura manchuriensis Kon'no

(all, $\times 1$)

- Fig. 1. Thick main stem, showing more than 10 round scars of branches around the node ; the internode is seen being traversed by 1.25 mm. distant furrows and further by several fine interstitial longitudinal striations between every two of the furrows. IGPS coll. cat. no. 78070.
- Fig. 2. Middle and upper part of the branch, thin axis lacking any scar of branch-base. IGPS coll. cat. no. 78063.
- Fig. 3. Main part of the branch, with the thin and slightly flexuous axis ; each lobe of a leaf-sheath is given off at rather an acute angle and asymmetrically on each side of the axis. IGPS coll. cat. no. 78067.
- Fig. 4. Apical part of probably the main stem, but no scar of the branch-base is recognizable at the node. IGPS coll. cat. no. 78080.
- Fig. 5. Lower part of the large main stem with a very long internode, 85 mm. in length ; two branches are preserved in continuity with the node (see also Text-fig. 2). IGPS coll. cat. no. 78066.
- Fig. 6. Middle and upper part possibly of the main stem. IGPS coll. cat. no. 78068.



PLATE 19

Schizoneura manchuriensis Kon'no

(all, $\times 1$)

- Fig. 1. Apical part of a small main stem, with a very short immature branch preserved in continuity with the node; terminal leaf-sheath of the branch is composed by thorough fusion of leaves of about 14 in number (see also Text-fig. 3). IGPS coll. cat. no. 78065.
- Fig. 2. Apical end of the stem, with a coherent leaf-sheath at the upper extremity. IGPS coll. cat. no. 78069.
- Fig. 3a. Middle part of a small main stem. IGPS coll. cat. no. 78071.
- Fig. 3b. Long immature branch terminates in a thoroughly fused apical leaf-sheath, consisting of 16 leaves. IGPS coll. cat. no. 78071.
- Fig. 4a. Lower part of a large main stem, showing an internode of 10 mm. in width, traversed by eight to nine ribs; two branches are preserved in continuity with the node, where more than 10 round scars of branch-bases are seen. IGPS coll. cat. no. 78066.
- Fig. 4b. Counterpart of the specimen shown in Pl. 18, fig. 5 and Pl. 19, fig. 4a; two branches are preserved in continuity with the node; the lowermost internode of the branch is much longer (50 mm. in length) than the next upper one (30 mm. in length). IGPS coll. cat. no. 78066.
- Fig. 5. Rhizome with a rhizome-branch in organic connection to the main axis; numerous scars of branch-bases of equal size are seen around the node; rootlet-like appendages densely cover the whole surface of both main and the lateral stems. IGPS coll. cat. no. 78072.
- Fig. 6. Lowermost part of the large main stem, showing irregularly ornamented cortical surface which is covered by minute rootlet-like appendages; nodal diaphragm with leaf-segments is seen in the lower end of this specimen. IGPS coll. cat. no. 78072.
- Fig. 7. Lower part of the large main stem, with three branches preserved in continuity with the uppermost node, where are seen many circular scars of the branch-bases; two sorts of leaf-segments are seen at this node, the free long and broad leaves, pointing backwards, represent the leaf-sheath of the main stem, while narrow leaves fusing into a lobe appear to represent the lowermost sheath-lobe of the branch. IGPS coll. cat. no. 78064.

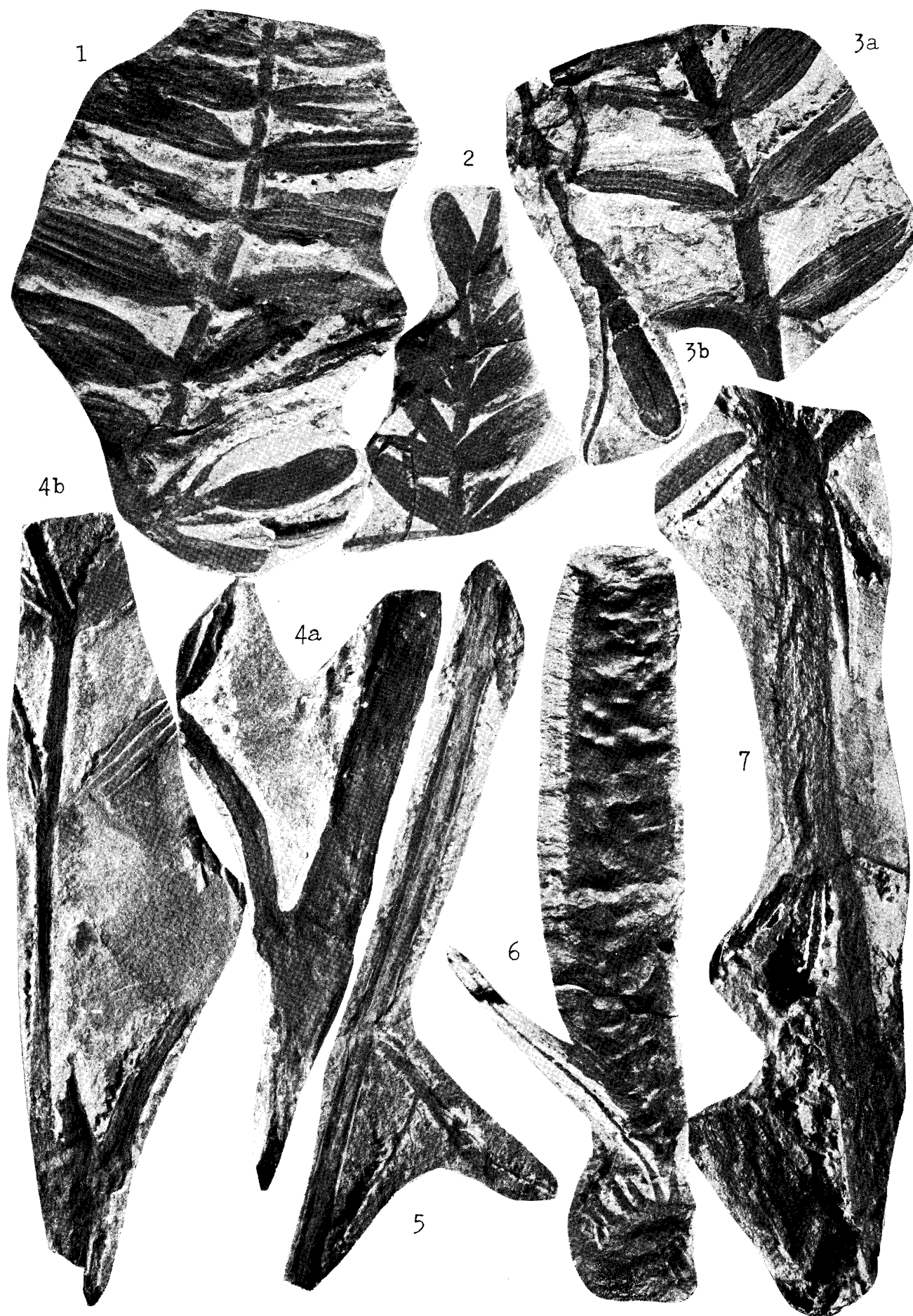


PLATE 20

Manchurostachys manchuriensis Kon'no

- Fig. 1. Type-specimen ; 1a is the side view of this specimen, showing the gently curved surface of the upturned cone-shape of the sterile leaf-sheath ; 1b is the back view, showing the characteristic features of the large sterile leaf-sheath, composed by intimate cohesion of the leaf-segments along sutural lines and penetrated uniformly by fine longitudinal nerves ; 1c is the front view, showing the fertile axis covered by clusters of sporangiphores (see also Text-figs. 4a, 4b and 4c) ; all figures $\times 1$. IGPS coll. cat. no. 78083.
- Fig. 2. Basal view of two successive sterile leaf-sheaths, showing their basal surface of bowl-shape, $\times 1$. IGPS coll. cat. no. 78085.
- Fig. 3. Type-specimen ; central fertile axis of 55 mm. in length is divided into seven internodes ; two upper internodes of them are separated by plane of diaphragm, which is shown five times enlarged in Figs. 4a, 4b and 4c. In the counter part of this specimen, though not figured here, six sterile leaf-sheaths are preserved in the rock-matrix, which are shown by thick lines in Fig. 3 of Text-fig. 4, $\times 1$. IGPS coll. cat. no. 78084.
- Fig. 4. Enlarged view of the cylinder of the fertile axis, separated from the specimen, above-explained ; 4a is the front view, showing numerous polygonal peltate discs being regularly superposed in longitudinal rows ; 4b is the back view, showing a large shallow hollow in its lower end, which represents the counterpart of the diaphragm of the cone-axis ; 4c is the view of the cross-section of the fairly flattened cone-axis, showing 23 sporangiphores in a whorl (also see Figs. 4a and 4b in Text-fig. 4) ; $\times 5$. IGPS coll. cat. no. 78084.
- Fig. 5. Surface view of a fertile axis, showing crowded polygonal or circular peltate discs arranged in numerous whorls, $\times 4.5$. IGPS coll. cat. no. 78086.
- Fig. 6. Two sporangiphores and one sporangium, immersed in balsam on slide glass ; photo by reflected light, $\times 10$. *Manchurostachys* slide no. 1.
- Fig. 7. Upper view of several sporangiphores, two of which show the upper feature of the individual peltate disc, $\times 10$. *Manchurostachys* slide no. 2.
- Fig. 8. Upper view of a peltate disc, showing the central depression representing the upper extremity of the sporangiphore-axis, around which six sporangia are grouped ; this specimen is obtained from the upper projected portion of the specimen shown in Fig. 4a, $\times 10$. *Manchurostachys* slide no. 3.
- Fig. 9. Mass of spores, each of about 12μ in diameter ; one black body seen in the right-hand and lower corner is a cluster of several spores ; photo by reflected light, $\times 184$. *Manchurostachys* slide no. 4.
- Fig. 10. Mass of spores, each of $11-13\mu$ in diameter ; macerated by Schulze's solution ; spores are of light orange colour in transmitted light, photo by transmitted light, $\times 760$. *Manchurostachys* slide no. 4.
- Fig. 11. Mass of spores, each of $10-14\mu$ in diameter ; macerated by Schulze's solution ; spores are of light brown colour in transmitted light, showing some surface ornamentation consisting of a central small depression and radiant lines, photo by transmitted light, $\times 760$. *Manchurostachys* slide no. 5.
- Fig. 12. Three groups of spores, each of $11-13\mu$ in diameter ; macerated by Schulze's solution ; spores are of dark brown colour or opaque in transmitted light, some of which show a central small depression and numerous lines of the equal strength radiated therefrom, photo by transmitted light, $\times 760$. *Manchurostachys* slide no. 6.

